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ABSTRACT

This paper deals with two applications of streak photography in everyday industrial and biological research and development endeavors. In each instance, the simplicity and low cost with which the data could be reduced to useful information and the ease with which it could be communicated to other technical personnel was an important side benefit.

In the first case, a laboratory built rotating drum streak camera with a 12" circumference, was used to study the performance of the new Olympus F-280 flash on an Olympus OM-4T camera. The strobing frequency, starting characteristics, duration under manual and camera control, flash relationship to shutter curtain position, flash initiation and curtain velocities were examined.

In the second case, a standard oscilloscope recording camera was modified to study the growth characteristics of a fungus culture growing under controlled laboratory conditions for periods up to one full week. The streak photographs, taken at ultra slow rates, were correlated with 2-dimensional photographs taken at regular intervals to eliminate ambiguity in the growth cycle when the photographs were included in a written report.

1. INTRODUCTION

This applications paper is the result of requests for solutions to two problems in which streak recording techniques using low cost and modified instrumentation were use d to gather, evaluate and communicate subject characteristics in a simple and direct manner.

2. PERFORMANCE CHARACTERISTICS OF OLYMPUS OM4-T WITH NEW F280 FLASH

The first project was set up to respond to a request by Modern Photography magazine to analyze the performance characteristics of the OM4-T camera coupled to the novel F280 long duration flash. Areas of interest dealt with actual vs. specified flash duration , manner of light management, synchronization characteristics, etc.

2.1 Streak camera

This work was undertaken with a simple rotating drum type streak camera illustrated in Figure 1. The film in the camera is wrapped onto a "blower fan" drum driven by a universal wound AC motor under the control of a variable transformer. The motor speed was monitored by a General Radio 1531 Strobotac. A 2 mm wide slit is located about 1 mm in front of the film surface.

Since this is a very basic camera, the film needs to be loaded onto the drum in the dark. It is attached to the drum emulsion side out and held in place with transparent tape. Because the rotational speeds are low, the tape is suitable for this purpose. Since it is also transparent, potentially valuable data is not lost due to the tape and fresh emulsion is available at least for the duration of one revolution.

Figure 1. Stylized arrangement of the streak camera showing construction and project layout details. Slits are emphasized in size for clarity.

2.2 Flash duration measurement

Determination of the duration of the electronic flash was carried out by aiming the flash directly at the camera. The flash head was masked down to leave a 1/2mm horizontal slit extending across the length of the flashtube. This slit was then centered within the slit of the streak camera at a reduction of about 2.5X making the effective slit width about .2 mm . The slit at the subject plane coupled to the one in the camera contributed to cleaner streak records due to a lessening of internal camera flare.

The film speed, thus the time base, was chosen to be a convenient 100 inches per second. Thus, the camera drum, which has a circumference of 12 inches, was rotated at 8. 33 rps and held at this value during photography by monitoring the shaft with the Strobotac .

After loading, a dim safelight was turned on and the camera was brought up to speed. At this time the OM4-T shutter was tripped which fired the flash. The duration of t he flash was studied with combinations of camera and flash on Manual and Automatic or Super FP modes and a range of camera speeds which varied from 1/2000 to 1/60 second.

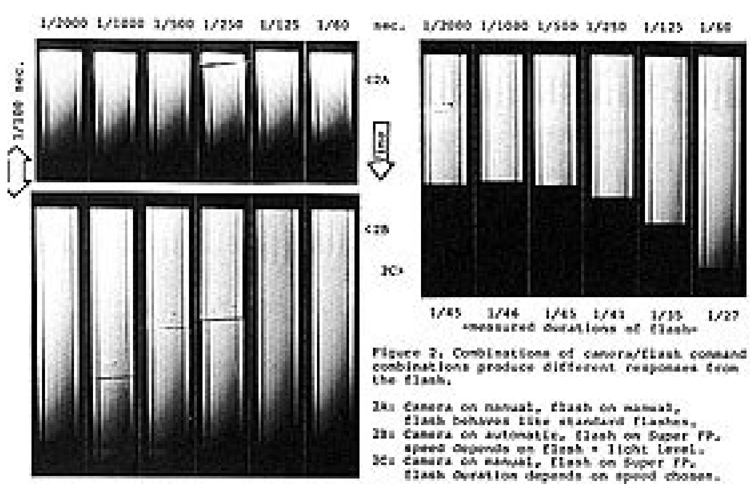


Figure 2. Combinations of camera/flash command combinations produce different responses from the flash.

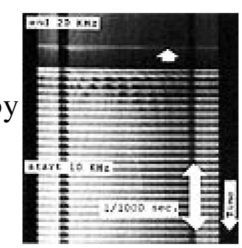
2A: Camera on manual, flash on manual, flash behaves like standard flashes.
2B: Camera on automatic, flash on Super FP, speed depends on flash and ambient light level.
2C: Camera on manual, flash on Super FP, flash duration depends on shutter speed chosen.

The results of this sequences of exposures, Figs. 2A and B, showed the changes in the behavior of the flash according to whether a single high intensity burst of light or an extended light pulse was produced. The latter, square wave type, is necessary in order for the flash to last at least as long as it takes the first and second curtains of the focal plane shutter to travel across the camera's image plane.

It was determined that when the flash was set on "manual" the flash duration and other characteristics are typical of small hand type electronic flashes. The duration is in the order of 1/1000 or so, not including afterglow which stretches the total duration to about about 1/250 second. This is shown in Figure 2A.

In the extended duration mode, however, the flash behaved in an obviously unique manner. The tests proved that the flash indeed provided something close to a square wave output. As long as the flash is set on Super FP and the camera on automatic, the flash is in control of the camera which sets itself to the exposure time required for proper exposure. This is the "synchro-sun" mode. In this test the flash duration was probably the longest that can be delivered due to the low ambient light level plus the slit added to the flash. The measured duration in each case was about 1/25 sec.. See Figure 2B.

From a close examination of the images produced by the flash in the extended duration mode, it was evident that the flash took on the characteristics of a stroboscope with a very high frequency of operation. With camera on "manual", speeds set manually and the flash on Super FP mode, its strobing duration was clearly controlled to last for a time dependent on the shutter speed chosen on the camera. The burst length varies from about 1/50 second to about 1/25 second in duration. This compensating action of the flash is most clearly seen at speeds of 1/250 sec. and longer. At the shorter times the intercourtain time is short compared to the minimum curtain travel time and the compensation can not be easily seen, Figure 2C.



To more clearly visualize the stroboscopic nature of the flash and to arrive at an accurate value for the strobing frequency, a series of photographs were made with the rotation rate of the camera increased by a factor of three. This provided a magnified view of the discharge pattern of the flash which, at this speed, extended roughly for one revolution of the drum when the exposure time was set to 1/60 second. This series showed a characteristic single initial discharge in the tube followed, about 1/5000 of a second later, by a steady 10 KHz discharge which increased gradually to about 17-20 KHz towards the end of the exposure. Figure 3, made at 1/60 second, is typical of this series of photographs. At the shorter times the variation in frequency was smaller.

Caption for Figure 3. Ignition characteristics and steady state and decay frequency of F280 Olympus flash.

2.3 Event time relationships

It was also desired to learn about the relationship between the time at which the flash turned on and burned and the position of the shutter curtains during exposure. This was accomplished by aiming the streak camera at the focal plane of the Olympus OM4-T camera and redirecting the light from the flash, located in the hot shoe, by way of two mirrors facing each other and placed at 45 degrees in a cardboard assembly located in front of the camera. This caused light from the flash to go through the body lens flange and out through the image gate of the Olympus to the streak camera, Figure 4.

The Olympus's gate was covered with an opal glass diffuser and masked with black tape leaving a 1/2 mm slit extending across it's long dimension. The image of this sl it was placed within the slit of the streak camera. To record a clean record of the initiation of the flash, an incoherent fiber optic cable was used with one end aimed at the flash head and the other end placed next to the slit constructed within the Olympus camera and in such a manner that it's image also fell within the slit of the streak camera. The rationale was that in this manner the timing relationships between the initiation and duration of the flash and the beginning and end of the expsure within the camera could be readily visualized, See Figure 4.

Figure 4. Stylized arrangement of the cameras, mirrors and fiber optic cable. Size of slit in Olympus gate exagerated for clarity. Function of fiber optic cable is to pick up initial stage of light output from the flash and direct it next to the slit in the Olympus body.

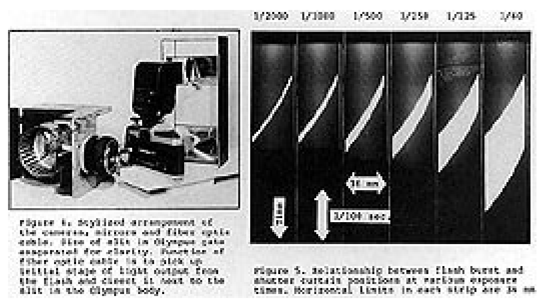


Figure 5. Relationship between flash burst and shutter curtain positions at various exposure times. Horizontal limits in each strip are 36 mm.

This proved to be the case and the results are shown in Figure 5. These illustrations clearly show that there is a constant 1/160 sec. delay between the time that the flash turns on and the arrival of the leading curtain to the edge of the image gate. This suggests that the flash is turned on by the first movement of the leading curtain. There is also a definite delay between the arrival of the second curtain to the far edge of the gate and the turning off of the flash. This delay is about 1/640 th sec. suggesting that the turning off signal may be sensitive to the stopping action of the trailing curtain.

Finally, in terms of exposure uniformity across the frame it is noted that the variation is minor and is most visible with the longest exposure times. Further, since there did not seem to be a marked variation in output as reflected by large changes in exposure, and the performance pattern of the flash seemed to remain constant except for duration, it is suggested the flash behaves identically at any speed setting but, because the duration is shorter, it uses slightly smaller amounts of energy from the capacitor when the shortest exposure times are selected.

2.4 Exposure time and shutter slit width measurements

As a side benefit to this study, the actual shutter curtain transit time can also be measured. It was found to be a constant 1/80 second for each curtain. Since the curtains travel 36 mm during this time,the average velocity of the curtains is about 2900 mm/sec.. Since the distance between curtain edges is equal to the exposure time, these can be measured from Figure 5 with reasonable accuracy, particularly for the longer times. The slit width at any location across the gate can also be measured and the data shows that the camera changes exposure time by changing the time between curtains which is reflected by a changing slit width. Better accuracy at the short exposure times could have been obtained by increasing the rotational speed of the drum in the streak camera. Finally, note that the addition of the lead time, the exposure time, the curtain travel time and the cut off time add up to the total duration of the flash in its extended duration mode.

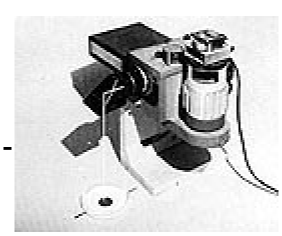
TABLE A

SET TIME	MEASURED TIME	SLIT WIDTH,mm	FLASH DURATION
1/60	1/64	>36	1/27
1/125	1/130	26	1/35
1/250	1/260	13	1/41
1/500	1/550	6	1/45
1/1000	1/890	3.5	1/46
1/2000	1/1400	2	1/45

3. STREAK PHOTOGRAPHY OF FUNGUS GROWTH RATE

The second project was undertaken for a local agricultural research center. A proposal was made to that research group that an extended duration streak record would al low the ready visualization, measurement and subsequent publication of the growth rate of a particular fungus. It was proposed that since a time lapse motion picture does not lend itself for publication and a sequence of instantaneous photographs contains "invisible" interpicture time, the combination of the sequence approach with the streak technique would provide the most complete publishable representation of the fungus growth pattern.

3.1 Streak camera



Because the spread of the fungus was so slow what was needed was a camera which also moved the film slowly. A surplus Fairchild 321-C strip oscilloscope camera was modified by mounting a standard Canon camera body flange on the front so that the flange to film distance remained the same as in a Canon camera (38.8 mm). A 1 RPH motor was fitted to the top of the standard motor of the Fairchild and attached by a flexible joint to the motor's shaft. Thus the drive power was provided by the new slow speed motor. Finally, since the camera lacked a magazine, a simple plywood box was mounted on the side of the camera to serve both as a film supply and exposed film storage chamber. Further, a 1/20 mm. wide slit made of two pieces of thin aluminum was installed behind the hinged film masks of the Fairchild. See Figure 6.

Figure 6. Modified Fairchild C-321

3.2 Photography and evaluation of fungus growth

The speed of the film could be varied by the selection of appropriate gear ratios built into the camera. It was decided to run the film at a speed of 31 mm per day or roughly 3.6 x 10-4 mm/sec. In combination with the above slit the exposure time was in the order of 2 minutes.

Since the petri dish could not be turned on its side and the camera design is too unwieldy for vertical use, the camera remained level during photography and so did the petri dish. The camera's direction of view was deflected down onto the dish by placing a mirror at 45 degrees in front of the lens. The petri dish was placed on a black velvet background to help emphasize contrast. The film chosen for recording was Kodak Tech Pan due to its inherently high contrast, relatively slow speed, and large density range. Sufficient light for use of an aperture of f:16 was provided by one 25 watt household lamp placed 4 feet from the dish at an angle of about 45 degrees to its surface.

There is no major quantitative analysis associated with this project. In Figure 6 it is clearly shown, however, that the fungus grew at a fairly steady rate of expansion taking about 6 days to reach the edges of the 4" diameter dish. This translates to a spreading rate of 1/2 the dish, or 2", over 6 days, which is .33 inches per day or .013 inches per hour. The only difficulty occured when the record was shown to the client. He did not think that the streak record would be appropriate for publication because it did not look like a "real" photograph. You be the judge!

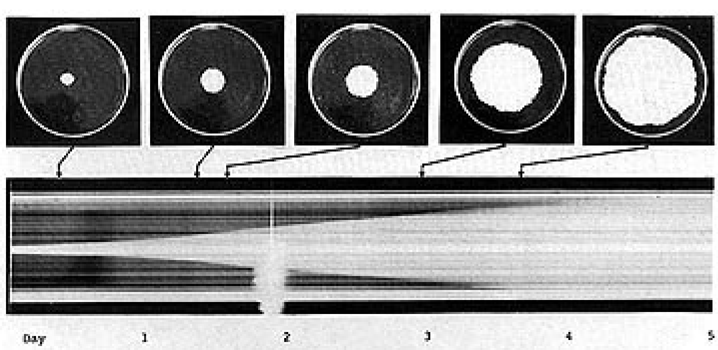


Figure 7. Instantaneous (simulated) and streak (real) records complement each ot her to give a more complete picture of the growth pattern of a fungus. The "glitch" on the streak record was due to inadvertent flash of light in front of lens.

4. CONCLUSION

In conclusion, the potential of simple and inexpensive streak techniques to yield a wealth of quantitative and qualitative information has been proven in these two applications. Streak techniques should be considered whenever there are budget constraints or complex and time consuming data analysis procedures which add considerably to the cost factor, when an unbroken time record or time vs. position record is desired and when it is possible to limit data gathering to a single line at a time at the subject plane .

If you have any questions please feel free to send e-mail to the author, Andrew Davidhazy